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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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THE MODERN PHOTOGRAPHIC TELESCOPE AND THE NEW ASTRONOMICAL PHOTOGRAPHY

BY G. W. RITCHEY

PART I.—THE FIXED UNIVERSAL TELESCOPE

At the time when I had just completed my first 24-inch mirror, which later became that of the 24-inch Yerkes reflector, I climbed, with a friend, to the summit of the dome of a celebrated observatory. It was an exceptionally brilliant midnight, and the northern Milky Way and the great Andromeda nebula were nearly overhead. The objective of a celebrated photographic refractor was so near us, just below, that we could have touched its cell with a yard-stick. My friend said: "This telescope should reveal marvellous things in those heavens and in that nebula." But those brilliant depths appeared so overwhelming, so unfathomable, and the beautiful lens so tiny, so microscopic for the task, that I said: "Even the greatest refractors seem hopelessly small for those great problems; lenses cannot possibly be made much larger than at present. Even the largest mirrors, which could certainly be made much greater in aperture than the greatest attainable lenses, would still be puny, pygmy instruments for those stupendous problems."

My friend said: "I do not wish to discourage you, but to warn you. Your faith and hope in great reflectors is misplaced. The English astronomers say that, and *they know*. They are the great reflector builders; they have had the experience of centuries,—from the time of Newton. The elder Herschel's two-foot mirrors were great successes; his four-foot mirrors were comparative failures.

Sir John Herschel went back to the two-foot aperture; there is one proof. The three-foot of Lord Rosse was a great success,—his six-foot a comparative failure, celebrated chiefly for its mere bigness; here is the second proof. Lassell's experience was practically thet same, a third proof. The four-foot reflectors of Paris and Melbourne are final proofs; both are almost complete failures; they have no more real optical power than a good six-inch objective. Common's three-foot was a great success, but you will see that his five-foot will prove to be a comparative failure. The record, the proof, is complete. The English have proved, for all time, that about 36 inches is the limit for reflectors. Speculum-metal mirrors have been proved to be too heavy for great sizes, their surfaces not permanent and their frequent renewal prohibitive. Very large glass disks, of the great thickness necessary, almost invariably break in annealing. You are wasting your efforts; if great reflectors could have been successful, this would have been accomplished long ago."

I said: "This is a new epoch; think of the Clarks and their unprecedented objectives; of Mantois and his unprecedented optical disks; of Warner and Swasey and their unprecedented telescope-mountings; of the World's Fair at Chicago and its unprecedented buildings. Think of the New York sky-scrapers,—an absolutely new departure in architecture; think of the unprecedented ocean-liners and battle-ships. But astronomy must surpass indefinitely these latter achievements, because its problems are indefinitely greater. Future optical mirrors will be made, not of solid disks, but built up of *glass plates*;—light, cellular structures, too large for transportation to high mountain sites, but transported in small pieces, and cemented together and figured *at* the high mountain sites. The glass-makers know how to make good glass plates, strong, rigid, highly-elastic; they have been making them for a century; these plates will be selected for thickness and for uniform coefficient of expansion; they will be flawless, homogeneous, without bubbles, without striae. I hope to make, and to use on that Andromeda nebula and on that Milky Way, a reflecting telescope with a practically perfect mirror,—not two feet in diameter, but as large in diameter as this dome, fifty feet. Even that will be infinitesimal in view of our problems."

Emerson says: "Hitch your wagon to a *star*." I say: "Think of

our future telescope in terms of the *universe*. Plan it, design it, refine it, perfect it, with the vision always before us of the stupendous depths which it must reveal and measure. Secure plates of low-expansion glass, pyrex or fused-quartz for its mirrors; invent new, better curves for its mirrors to give more concentrated, more symmetrical telescopic images; reduce the flexures of its mirrors and mounting practically to zero; protect it from the effects of tenperature changes. Rotate it, frictionless, floated in mercury, turning as smoothly and accurately as the earth on its axis. Invent special photographic plates for it, with accurate surfaces and with special sensitive emulsions for its special needs. Invent photographic accessories and plate measuring machines for it, as accurate as Rowland's machine for ruling diffraction gratings. Search the Earth over and over, with the aid of consciencious, competent experts, for the best site for it. Demonstrate the practicability of it. Write articles and books for it; lecture for it; argue for it; plead for it. Fight for it, the opposition of reactionaries. Interest millions of the best men and women in it; and in this generation we shall attain it. It will repay us immeasurably for all our efforts, for our lifelong devotion. In this generation we shall secure, with its aid, astronomical photographs of many times greater refinement, and, as a result, astronomical measurements of many times greater accuracy than are possible today."

The question of the most efficient type of mounting for very large photographic reflectors has become of much importance. The new aplanatic combination of two optical mirrors makes possible a very short, compact, equatorial type, of extraordinary efficiency, convenience and economy.[1] But the successful development of the built-up, cellular construction of mirror-disks[2], which makes possible the use of low-expansion glass, pyrex and fused quartz for large apertures, has demonstrated the possibility of extreme refinements and of very great sizes of photographic reflectors which make desirable a still more efficient type of mounting than even the new, compact equatorial type.

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[1]Ritchey and Chrétien, *Comptes Rendus* des séances de l'Académie des Sciences, tome 185, page 266, séance du 18 juillet, 1927.

[2]Ritchey, *Comptes Rendus*, tome 181, 1925, page 208; and *L'Astronomie*, tome 40, février, 1926, page 57.

Built-up, cellular disks are very light. In addition, this construction enables us to use a large number of small units of glass, pyrex or fused quartz, instead of a single large unit. For example, in building up a cellular pyrex disk of 12 feet diameter, the largest separate units of pyrex required would weigh 400 pounds each; whereas a solid pyrex disk of 12 feet diameter, of the minimum thickness allowable, would weigh 16,000 pounds. The proportion of weights is as 1 to 40, and applies also to the use of fused quartz, and to all large sizes of disks.

In my studies of cellular mirror disks I have from the first taken as models the honeycomb, the egg-shell and the spider's web. It seems so ridiculous to insist upon using for a great optical mirror a heavy, solid disk, expensive, almost prohibitively difficult to cast and to anneal, and weighing several tons, in order to support in perfect optical form a silver film weighing only a very small fraction of an ounce! Would it not be as sensible to insist upon building a great bridge as a solid bar of metal, or an Eiffel Tower as a solid mass of masonry? And will not such changes in our ideas as are suggested by this example enable us to think in broader terms of the instruments and methods with which we attempt to solve the problems of the universe?

Optical mirrors made with cellular disks having positive (forced) ventilation, when exposed to such temperature changes as ordinarily occur in the open dome at night, do not suffer changes of figure or of general curvature sufficiently large to be detected by the most sensitive optical tests. Large plane mirrors *remain plane* when in use on the sky. Large coelostatic telescopes of the highest optical performance are thus made possible for the first time.

I have been able not only to design and construct several reflecting telescopes of progressive sizes up to the largest, (including their mirrors), but also to use several of them in astronomical photography. While designing and constructing, and later while using, each of these instruments I have studied constantly the possibility of improvements and refinements, in order that each successive telescope should be not only larger than its predecessor, but also better, more efficient, in full theoretical proportion to its increased size. Such a combination of design, construction and experience in use; together with such a progression of sizes, improve-

ments and refinements, must inevitably prove to be an asset to Astronomy; a break in their continuity must inevitably result in serious loss. The principle is self-evident. If illustrations were needed, witness Fraunhofer and his successors; the house of Mantois; Alvan Clark and Sons; Warner and Swasey; Brashear and McDowell.

When I had completed the mirrors of the 100-inch of the Mt. Wilson reflector I gave much study for eight years to the detailed designs of a fixed, vertical, universal type of reflecting telescope, with coelostat, and with cellular mirrors. In this design I endeavoured to overcome the technical difficulties and the inconveniences of all kinds which are encountered with very large equatorial reflectors. This type is incomparably well adapted for the highest requirements of astronomical photography, and of astrophysical work with very large and elaborate accessory instruments.

The first detailed designs, completed in March, 1924, are for a vertical telescope with three principal concave mirrors each five meters (16.4 ft.) in aperture, and with the coelostat plane mirror and the second large plane mirror each 6 meters (19.7 ft.) in diameter. The six secondary mirrors, (Newtonian plane, Schwarzschild concave, Cassegrainian and Ritchey-Chrétien convex), also of cellular construction, vary from 1.52 meters, (5 feet), to 1.83 meters, (six feet), in diameter. A general view of the arrangement of this telescope is given in Fig. 2, (although this figure illustrates a still later deisgn in which only Schwarzschild and Ritchey-Chrétien combinations of mirrors are used). In both designs the coelostat is far above the ground, which is an indispensable condition for obtaining the best possible atmospheric definition. The coelostat and the mounting of the second large plane mirror rest upon the massive, horizontal summit of the inner building, which is of reinforced concrete construction. An outer building of very strong steel construction, which is entirely separate from the inner concrete building, surrounds the latter, protects it from wind, weather and sudden temperature changes, and supports the dome. This outer building and the dome are in turn protected by an exterior light, sheet-steel sun-shield. The two sheet-steel walls are separated by ample ventilating space, and all are painted white.

As shown in Fig. 2, two stories or floors of the inner telescope building are below the ground-level, (marked *Sol*). In the first designs the vertical distance between floors 1 and 3, (as numbered

on the right-hand side), is 18 meters (59 feet). The vertical distance between floors 3 and 4 is 26 meters (85 feet). The total height from floor 3 to the summit of the dome is 53 meters (174 feet). The interior diameter of the dome is 32 meters (105 feet); it should be noted that this diameter of dome is for a universal telescope of five meters (16.4 feet) aperture. The interior diameter of floors 1, 2 and 3 is 34 meters, (111 feet).

The second large plane mirror in the dome receives the stationary beam of light from the coelostat, and reflects it vertically downward, centrally, in the fixed vertical tube of the telescope.

On the first floor below the outside ground level, three or more large concave mirrors lie horizontally, face-up, each on its own complete mechanical flotation-system and carriage, the latter rolling on straight horizontal rails. Thus any one of these mirrors, as desired, can be moved quickly into the exact center of the telescope tube, with automatic adjustment and alignment with reference to the fixed, vertical optical axis of the telescope.

In the design, the three large concave mirrors are respectively: one paraboloidal mirror for one Newtonian and three Cassegrainian combinations; one new-curve concave mirror for one Schwarzschild combination; and one new-curve concave mirror for one Ritchey-Chrétien combination.

Each of the carriages supporting the smaller, secondary mirrors for these combinations also roll on straight, horizontal rails into exactly central position, with automatic adjustment and alignment, each in its correct plane with reference to its large concave mirror.

Each of the accessory instruments:—prism-spectrographs, grating-spectrographs, thermo-couples, bolometers, radiometers, interferometers, photographic apparatus for direct photography with low and high powers,—*all* of whatever size, elaboration and refinement desired, and each in its own enclosed, constant-temperature laboratory with insulating walls and with concrete floor and piers, can be rolled smoothly on straight, horizontal rails, into exactly central position, in perfect adjustment and alignment. These accessory instruments are all on the lowest floor, the second floor below the outside ground-level.

The rolling carriages supporting the telescope mirrors, large and small, and those carrying the accessory-instrument laboratories,

are moved electrically, smoothly, all of them horizontally, into and out of their exact central position. Whatever be the size of the telescope,—whether the aperture be one meter or ten meters, the interchange from any one complete combination of mirrors and accessory instrument to any other combination, in complete adjustment and alignment, ready for instant use, can be accomplished in four minutes.

The square, vertical tube of the telescope consists, primarily, of four vertical, square columns at its four corners. These columns, above the third or ground floor, are of strong steel construction, and are separate from the concrete inner building. These steel columns are connected together by horizontal members of steel, and all of these parts are heavily insulated with cork, so that expansion and contraction from temperature changes are very slow and small. The horizontal steel girders and rails, on which roll the carriages of the secondary mirrors, are supported entirely by these four vertical, insulated steel columns. At and below the ground-floor the four vertical columns are of concrete, and may be constructed, if desired, as a unit with the ground-floor and the two floors below.

The combinations and focal ratios which were planned for the mirrors described above are as follows:—(*a*) one Schwarzschild type with one large concave and one small concave mirror, giving a very large field together with the small ratio of focal length to aperture of 9 to 3, or 3 to 1; (*b*) one Newtonian with paraboloidal mirror, focal ratio 6 to 1; (*c*) one Ritchey-Chrétien combination with one large concave and one small convex mirrors, focal ratio 6.8 to 1, (4×1.7); (*d*) one low-power Cassegrainian combination, focal ratio 12 to 1, (6×2); (*e*) one medium-power Cassegrainian, focal ratio 18 to 1, (6×3); (*f*) one high-power Cassegrainian, focal ratio 30 to 1, (6×5).

The above conbinations for the fixed, universal type of telescope are the ones planned while I was engaged in developing the new types in America, 1910-1924. In 1924-1928, while in Paris, I have had the opportunity of renewing the consideration of this subject with great thoroughness with M. Henri Chrétien. Without changing the general plan or the mechanical arrangements of the universal type, we have decided to omit entirely the Newtonian and Casse-

grainian combinations, and to use only those combinations which give much smaller and more symmetrical images and larger fields. One of the highly favourable arrangements is the following, which gives five combinations and focal ratios instead of the six described above, but with a much better progression. This arrangement requires four large concave mirrors instead of three, and five small secondary mirrors instead of six.

(*A*) One Schwarzschild combination, focal ratio 2.75 to 1.

(*B*) One Schwarzschild combination, focal ratio 4.0 to 1.

(*C*) One Ritchey-Chrétien combination, focal ratio 6.8 to 1, (4×1.7).

(*D*) One Ritchey-Chrétien combination, focal ratio 12.0 to 1, (5×2.4).

(*E*) One approximate Ritchey-Chrétien combination, using the same large mirror as (*D*), but a different secondary mirror, focal ratio 20.0 to 1, (5×4).

With this arrangement a universal telescope with 5-meter concave mirrors and 6-meter coelostat and second large plane mirrors, would have available, with large fields and extremely small, round star-images, the following series of focal lengths:

(*A*) 13.75 meters, (*B*) 20.0 meters, (*C*) 34.0 meters, (*D*) 60 meters, (*E*) 100 meters.

Some of the marked advantages of the fixed, universal type of reflecting telescope may be enumerated as follows:—

(1) The convenience, comfort and safety of the observers, (and their consequent ability to do skilful and rapid work,) are perfect; and *equally so* whatever be the size of the telescope,—whether the aperture be one meter or ten meters.

(2) Every known refinement for visual, photographic, spectrographic and physical-laboratory observations can be used under the most perfect laboratory conditions, and therefore to the utmost limit of its possibilities.

(3) Every known useful form of reflecting telescope: Newtonian; Cassegrainian combinations of different focal ratios; the large-field types with small, symmetrical images, Schwarzschild and Ritchey-Chrétien, of varying focal ratios, can be used, interchangeably, as desired.

(4) Accessory instruments: astrophysical apparatus of all

kinds; photographic attachments for direct photography with low and high powers; the elaborate instruments for guiding, occulting and re-focussing in planetary and lunar photography with extremely high powers,—all of these, of any size, refinement and elaboration desired, each in its own enclosed constant-temperature laboratory, can be used, interchangeably, as desired.

(5) In long-exposure photography, direct and spectrographic, all of the mirrors in use, excepting only the coelostat plane mirror, lie in unchanging position throughout the exposure. The same is true of all parts of the telescope mounting, excepting only the coelostat. During a given time of exposure the polar axis of the coelostat rotates only one-half as fast and as far as that of an equatorial telescope. In the present design the *entire* combined weight of the polar axis, mirror-cell and mirror of the coelostat are supported directly from underneath by mercury-flotation; this gives extreme smoothness of rotation, and at the same time a very high degree of freedom from flexures in the coelostat. All of these conditions, and many others, give to this type of telescope a degree of stability of adjustment and alignment of all parts, optical and other, which is unique, and which is indispensable for the highest attainable perfection of astronomical photography.

Every type of telescope presents its own peculiar difficulties. Some of the criticisms which have been made in regard to the fixed, vertical, interchangeable type are as follows:

(*a*) All stationary types have been subject, in the past, to the fatal objection that the large plane mirrors of the coelostat or siderostat were subject to continual change from optical flatness, as a result of temperature changes. This objection disappears entirely with the use of the cellular construction of mirrors. (See third paragraph on page 162.)

(*b*) All fixed types are of course subject to the additional loss of light by reflection from one or two large plane mirrors. There is no complete remedy for this, although this loss can be very greatly decreased by keeping *all* of the silver surfaces *always* well burnished by means of a *special, highly-efficient* burnishing mechanism; both for higher percentage of light-reflection, and because this prevents, to a surprising degree, deterioration of the silver film. Keeping the silver surfaces clean and dry when not in use is of course another

great help. Whether any kind of extremely thin protecting lacquer can be used on the silver surfaces to keep them always at the highest point of reflective power, without injuring to some extent the optical performance of the mirrors, is a question which has never

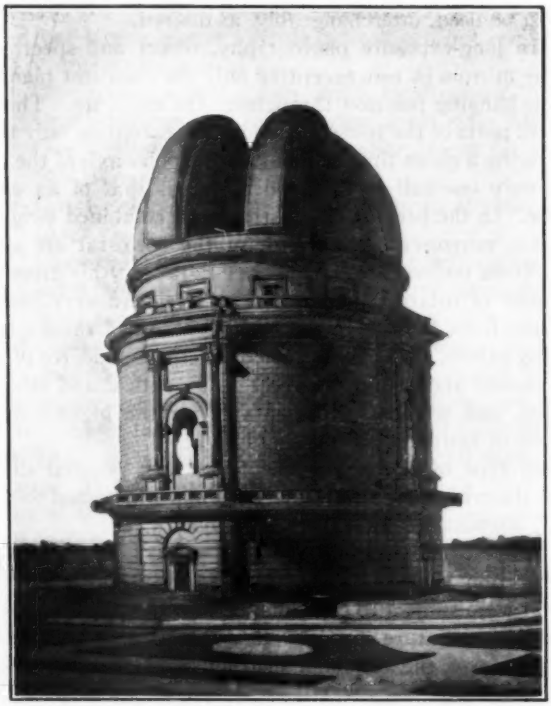


Fig. 1.—Exterior Elevation of the Fixed, Vertical, Universal Telescope.

been satisfactorily answered in the case of very high magnifying powers. It is one of the many laboratory problems which I am attempting to solve.

In my opinion the advantages of the fixed, vertical type, especially for very large sizes, greatly outweigh the disadvantage

of the loss of light from the two additional reflections. Some of the advantages referred to are those enumerated on pages 166, 167, still others will be described briefly near the end of this article.

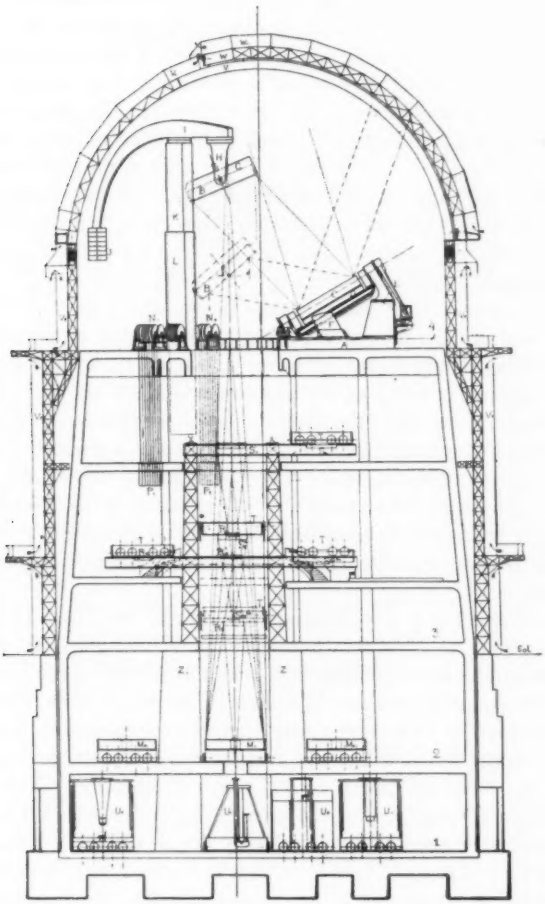


Fig. 2.—Vertical Section: Diagram Showing Interior Arrangement of Fixed, Vertical, Universal Telescope.

Persei, and the Crab nebula M.1. *Tauri*; the ring nebula M. 57 *Lyrae*; the Dumbell nebula M. 27 *Vulpeculae*; the planetary nebula H. IV. 18 *Andromedae:* the great globular star-clusters M. 13 *Herculis*, M. 92 *Herculis* and M. 3 *Canum*; and thousands of other celestial objects almost equally interesting and important. I shall return to a consideration of this point in still another way in the final paragraphs of this article.

(*d*) The general plan of interchangeable mirrors and accessory instruments has been criticized on several grounds. With the very quick interchange and the stability of adjustment and alignment possible with the fixed universal type, all of these criticisms disappear except the following one:—that this plan is not *economical*, because only one combination can be used at one time,—all of the other combinations being idle during that time; in other words, that it would be more economical to have each of these combinations used as a complete, independent telescope. Without taking space to make a detailed comparison of these two plans, I shall give a partial and practical answer to this criticism by describing briefly a night's work in direct astronomical photography which could be done with this interchangeable telescope. The following is based upon my own experience in astronomical photography on hundreds of long nights, at Yerkes and Mt. Wilson Observatories.

What we call "seeing", or atmospheric definition, varies greatly, and sometimes quickly, even on brilliant, cloudless nights, and even in the best locations known at present. In general, it is impossible to predict with accuracy what the night conditions will be; we must be guided in our programme of work by the changing conditions as they occur. The quality of seeing is indicated by the degree of sharpness of the image of the "guide-star" which the observer watches constantly in guiding and occulting. He estimates the quality of the "seeing" on a scale of 10; 1 to 2 being very bad, not usable; between 2 and 3 being usable only with the smallest focal ratio of 2.75 to 1; 5 being moderately good, 10 being the most perfect ever seen.

Let us assume that immediately after dark, atmospheric definition is at 5 on a scale of 10; the observer therefore changes to the combination best adapted for moderate seeing, that is, combination (*C*), page 166, with medium focal ratio of 6.8 to 1,—a medium

magnifying power for a very fine climate. He begins a long-exposure photograph of a spiral nebula with this combination, and continues it for two hours, when he notices that the wind is gradually increasing and the definition gradually falling. When, in another half-hour, definition has gone down to 4, which is his low limit for this focal ratio (6.8 to 1), his assistants change the mirrors to combination (*B*), with focal ratio 4.0 to 1. He puts away in a dark drawer the plate-holder and its guiding eyepieces used for the photograph

Fig. 4.—Professor Ritchey and his Staff, of the Dina Optical Laboratory, Paris Observatory.

The south facade of the observatory is in the background. The large windows of the second floor are those of Professor Ritchey's laboratory.

begun with (*C*); and he continues with combination (*B*) a long-exposure photograph of a very faint, extended nebula which he had begun on the preceding night with that combination. Definition continues between 4 and 3 until midnight; if it had fallen as low as 3 he would have changed to the lowest-power combination (*A*). At midnight he has secured the full time of exposure desired for this photograph with combination (*B*). Since definition continues

the same he starts another long-exposure photograph of another faint extended nebula, with the same combination (*B*). At one o'clock he notices a decrease in the wind, and a very marked improvement in definition;—so marked that he goes out on the balcony of the dome, expecting to see a low fog forming in the valleys around and below the observatory. He finds that this is so, and he returns to the telescope and to work, to see whether definition continues to improve rapidly, or goes downward again. Within half an hour definition goes gradually up to 7, as the wind dies down to a dead calm. He knows that with this calm, and with this low fog he may expect extraordinary definition, perhaps as high as 8 or 9. He cannot afford to waste such precious conditions on low-power work, and he does not need to do so, because he has a *quickly-interchangeable* telescope. He takes a chance, and changes to the highest-power combination (*E*), with focal ratio 20 to 1, and to the photographic accessory-instrument for planetary photography with very high powers. He is not taking a serious chance, because he can change back to any other combination, if necessary, in four minutes. Definition improves to 9 and to 9.5. It is his great, long-awaited opportunity, the one supreme hour of a thousand! He and his assistants work quickly, skilfully, smoothly, in photographing very bright planetary nebulae and the planets with magnifying powers of many thousand diameters. Every known invention for their convenience, comfort, facility and speed in their strenuous work of guiding, occulting, re-focusing, with extremely high magnifying powers, is provided and at hand, in the stationary, constant-temperature laboratory containing this high-power photographic apparatus. All of the extreme speed and skill, like those of the *virtuoso*, which they have acquired by long training with the double-slide practice-machine, stand them in good stead now, and enable them to photograph smaller details, and more delicate contrasts of shading and colour than any eye can detect visually with the same aperture.[1] But without the quickly interchangeable telescope the nearly perfect atmospheric conditions, which occur so rarely, and which continue for so short a time, could not have been taken full advantage of, unless, indeed, a complete, separate telescope, fitted

[1]Ritchey, *L'Astronomie*, April, 1928, paragraphs 46 and following.

for photographic work with the highest powers, had been kept always ready and waiting for such conditions.

At favourable observatory sites, many nights which are, in general, suitable only for low-power photography have intervals one or two hours in duration, usually after midnight in California, when much higher powers can be used. With this interchangeable telescope those favourable intervals can be used to priceless advantage in photographing with high powers such objects as the small, bright planetary and annular nebulae, the nuclei and other bright condensations of the spiral nebulae, the highly-condensed central parts of the globular star-clusters, the bright central regions of some of the gaseous nebulae, and similar objects. This is a great field of work of profound interest and importance, but hitherto almost entirely unexplored with high magnifying powers.

Before closing this article, I wish to call attention to several refinements which must reach their highest development in the fixed, universal telescope, and which may therefore be added to the advantages of this type of telescope enumerated on pages 166, 167.

The best combination of two optical mirrors known, so far as the symmetry and concentration of its out-of-axis images, alone, are concerned, yet presents such extreme difficulties in its efficient use, that even its inventor, Schwarzschild, considered these difficulties prohibitive. He therefore adopted another form, not nearly so good with respect to its images, but shorter, and having a field more nearly flat.[1] In both forms here mentioned, many of the serious practical difficulties are very much reduced when these telescopes are used as fixed ones, with coelostat. The fixed, vertical, universal type, (itself made possible by the cellular construction of mirrors), makes available for Astronomy the first and better Schwarzschild form just mentioned, in which the star-images are practically only diffraction-disks all over a field two and one-half degrees or more in diameter; and this with an equivalent ratio of focal length to aperture of only 3 to 1. All forward-looking astronomers will be as profoundly interested in this seemingly incredible result as I am. Backward-looking astronomers will oppose the

[1]K. Schwarzschild. Theorie der Spiegeltelescope, Potsdam, 1905; and Ritchey, *l'Astronomie*, January, 1928, page 33, and April, 1928, paragraphs 24 and 25.

A VISIT TO TWO FAMOUS OBSERVATORIES*

By W. H. Christie

At the second seminar held this year at the Dominion Astrophysical Observatory, the writer gave an account of a recent visit to the Mount Wilson and Lowell Observatories; the former at Pasadena, California, the latter at Flagstaff, Arizona. In accordance with the policy of reporting the subject matter of these weekly seminars for the Journal this much abbreviated account is written.

The first observatory to be visited was that on Mount Wilson and here, through the kindness of the director, Dr. W. S. Adams, I had the opportunity of seeing the work of that great institution. The instrumental equipment of the Mt. Wilson is unapproached by any other similar institution in the world, consisting as it does of the great 100 in. and 60 in. reflectors, the 150 and 60 ft. tower telescopes, two small refractors, the Snow horizontal telescope and, under construction, the new 50 foot interferometer.

Of the time spent at this institution several days were occupied by a visit to the mountain, the summit of which is about fourteen miles by road from the office buildings in Pasadena and 6000 feet high. Here I was entertained at "The Monastry", the mountain home of the astronomers. While on the mountain, although the weather was not very favourable, I was fortunate enough to be able to see the quality of the optical parts of the great 100 in. when Dr. Hubble showed two other visitors and myself Jupiter and the Great Nebula in Andromeda. Although the seeing was not of the best and clouds were coming up from the east, the markings that could be seen on Jupiter hinted of the quality of the images that might be expected on a good night. The tremendous light-gathering power of the telescope was emphasized, when it was turned on the outer arms of the Great Nebula, when the field could be seen spangled with tiny points of light—individual stars in an island universe far beyond the limits of the Milky Way.

An evening spent with Dr. A. H. Joy, working with the spectrograph at the Cassegrain focus of the 100 in. showed the conveniences of the telescope, which were much admired. Full control of the

*Presented at Seminar No. 54, Dominion Astrophysical Observatory January 13, 1928.

telescope and observing platform on which the observer is seated is at one's finger tips in the form of a number of switch buttons. Thus, by the pressure of a finger, the telescope can be focused; the guiding accomplished; the observer's platform moved up or down, in or out and sideways at the observer's will.

No visit to Mt. Wilson is quite complete without a trip to the top of the 150 ft. tower in the 'bucket' by which it is reached. Here at the top, where the coelostat mirrors feed the objective, a wonderful panorama of the majestic Sierra Madre range, of which Mt. Wilson is a member, is obtained, while the various buildings of the observatory are seen scattered over the mountain top below.

The huge spectrographs and spectroheliographs below the towers were much admired, both for their beautiful mechanism and the perfection of their optical parts. Several spectroheliograms were taken by Mr. Humason in my presence with the 60 ft. tower instrument, and measures of the polarity of sunspots in the regular routine work were made with the 150 ft. tower telescope. With the 75 ft. spectroscope of the 150 ft. tower the spectrum is spread out into a band many feet in length which, with its countless absorption lines, is well worth seeing.

The optical shop and the machine shop in Pasadena were visited with much interest; in the former a small mirror was being figured, and in the latter several pieces of apparatus were under construction, including a spectrograph with several distinctive features. The physical laboratory was also visited and the wonderful equipment hinted of the important researches being carried on there.

While at Pasadena the writer attended a lecture under the auspices of the Astronomical Society of the Pacific and heard Dr. Hubble speak on "Beyond the Milky Way". The delightful manner in which he presented his subject greatly enhanced the beauty of an exceedingly interesting lecture. In this lecture he conducted his listeners, step by step, from this world of ours out to the sun, the stars, the limits of our island universe—the galaxy—then out to the island universes beyond, showing how man's sounding rod has gradually increased in length until today he is able to sound space unto the limits of the telescope itself. As the reader may know, Dr. Hubble is the pioneer who bridged the vast distance separating our own from the other systems in space.

Another interesting lecture heard was one given by Dr. P. W. Merrill, in which he described his application of Bowen's utilization of "forbidden combinations" in the energy levels of iron, thus accounting for many new lines in the spectrum, as Bowen did with oxygen in his discovery of the origin of the "Nebulium" lines.

Lowell Observatory, about eighteen hours run on the Santa Fe railroad, was next visited. It is situated on a hill about three hundred feet high, known as Mars Hill, one mile and a quarter west of the town of Flagstaff, which has an altitude of 7,000 ft. It is here that so much work has been done on the planet Mars, which has been observed systematically since 1896 by the late Dr. P. Lowell and his associates. The instrumental equipment consists of one of the finest—if not *the* finest—refractors in existence, of 24 in. aperture and also a 42 in. reflecting telescope.

One of the most striking things about Flagstaff is the remarkable clarity of the atmosphere. Here, in the pure desert air, it is possible to see 7.5 magnitude stars with the naked eye. The daylight sky is of the deepest blue and Venus and Jupiter were both seen in broad daylight. The former was most striking, while the latter was readily seen when pointed out.

Though slightly out of place, it might be of interest to mention the excitement witnessed in Los Angeles at the daylight appearance of Venus. The sidewalks were crowded with people staring up at this phenomenon, for here, in the canyon-like streets, it was easily seen in the forenoon.

A large number of photographs of the planets taken by Mr. E. C. Slipher were examined, especially those of Mars, in which the so-called canals are clearly seen. On examining these photographs one is compelled to ask how it is that these linear markings can be photographed and yet remain invisible to so many observers. These markings do not appear as hazy streaks in the best of the photographs but as fine dark lines almost at the limit of resolution of the photographic plate; the oases, themselves, are difficult objects, appearing as tiny dots on the photographs. It is a great pity that these beautiful photographs cannot be reproduced, but the fine detail is lost when an attempt is made to do so. The Thoth, a strong curved canal running east and north from the Syrtis Major, is most striking on a large number of the plates. Out of curio-

sity the writer made a sketch from one of these photographs and compared it with the drawing made at the telescope at the time the photograph was made. No less than sixteen of the 'canals' were found to correspond exactly with those of the drawing. The careful examination of these photographs, several of which were presented at the seminar, at once dispels any idea that these strange linear markings are due to contrasting areas of light and shade as some have suggested; that they are truly linear there is every indication.

The twenty-four inch refractor, which I had the opportunity of using several times, surpassed all expectations. At moments of good seeing the fine detail visible on Jupiter defied one to reproduce it, the excellent photographs taken by Mr. E. C. Slipher alone beginning to approach that which may be seen. The lunar surface was examined with this exquisite instrument and revealed marvellous detail. Venus when examined showed those faint dusky markings which characterize it.

While at Flagstaff the writer twice visited the famous meteor crater,—the first time with Mr. Bennett and the second time with a party driven by the Director. The first sight of this enormous hole in the earth's crust, some three-quarters of a mile across and seven hundred feet deep, was awe-inspiring. For miles around the crater, huge fragments of limestone may be seen which have been hurled out by the impact of the great meteor, or cluster of meteors, which caused this vast pit, while the crater walls are piled high with finely powdered limestone, pulverized by the titanic blow dealt it.

On the first visit, Mr. Bennett and I spent considerable time in searching for fragments of meteoric iron, and although many fragments of shale-ball were found only one of iron was picked up, and this by my companion. Some of these fragments were shown at the seminar. Several trips to various other objects of interest were made through the kindness of Dr. Lampland and Mr. Bennett, among these being one to the lava beds and cinder cones of one of the extinct volcanoes in the vicinity, Sunset Mountain, so called because of the ruddy appearance of its crest, as though tinged with the rays of the setting sun.

Through the courtesy of Dr. Lampland, I had the opportunity of seeing the apparatus with which he has made so many excellent

radiometric measures of the planets, and was greatly interested in the exceedingly fine thermocouples which he has succeeded in making. The results of his work on the planet Mars are most interesting. A number of plates of variable nebulae were examined under the blink comparator which showed the changes which various parts of some of the nebulae undergo.

The time that the writer spent at these two institutions was altogether too short, every moment was filled with interest and it is with pleasure that I take this opportunity of expressing my thanks to those whose courtesy made my visit so enjoyable.

RADIO TALKS ON ASTRONOMY, OVER CFCT, VICTORIA, B.C.

By W. E. Harper

III. THE HEAT OF THE SUN

(March 14, 1928)

IT would seem appropriate in these balmy days of spring, when the warming rays of the sun are kindling everything into life, that we pay our respects to it as the source of all such light and heat. Without it life, as we know it, could not exist upon the earth for if the earth were cut off from the solar rays for a single month, all life would be extinguished and our planet become a frozen waste.

While it may not have occurred to us to realize the fact, it is certainly true that the energy stored up in wood, coal, oil and gas has come to us from the sun. Under the influence of sunlight the carbon dioxide of the atmosphere is taken in by the leaves of trees and plants and acted upon to form plant growth. It is true that only a small fraction of the solar energy falling upon the leaves is thus chemically transformed and stored, but continuous action over long ages always results in a great growth of vegetation upon the land surface of the globe. In the upheavals that have occurred during geological times such forests have been buried and preserved, in the forms just mentioned, for man's use today. Every heart beat, every breath, every act performed draws its working power from the accumulated solar energy stored up in plant and animal growth, —in "canned sunshine".

The sun is still active in this and other ways as well. By its power it draws water into the atmosphere; the wind carries these moisture-laden clouds to higher levels, whence it falls as rain or snow, ever renewing the reservoirs built for hydro-electric power.

First, let us get an idea of its size and distance. The earth is a globe whose diameter is roughly 8,000 miles, whilst that of the sun is 864,000 miles, or 109 times as great. Since the volume of a body varies as the cube of its diameter we readily deduce that the sun is approximately one and one-third million times the size of the earth. Moreover, from methods akin to those of the surveyor in mountainous districts we have learned that its distance is 93,000,000 miles, but even across this great stretch come its warming rays and we are forced to the conclusion, if we think at all, that it must be an excessively hot body to radiate its heat so far.

Our range of temperature on the earth is a limited one. On the ordinary Fahrenheit thermometer 32° indicates the freezing, whilst 212° indicates the boiling point of water. This covers the range of ordinary human experience. But the melting point of lead is 1000°, of iron 3000°, while the electric furnace furnishes a temperature of 6500°.

How can we determine these high temperatures? To a great extent it is by the colour exhibited by the glowing substance. An iron poker in the furnace becomes dull red at first and as its temperature increases we see it becoming white hot. The same is true in the case of an electric bulb. The filament at first is dull red but rapidly becomes white hot. In short, this is the principle of determining high temperatures, for the colour signifies the wave-length of the predominating radiations and spectral analysis of the light reveals the corresponding temperatures.

Without going further into the theory, suffice it to say that the surface temperature of the sun is 11,000° Fahrenheit. On the Centigrade scale used by scientists, the figure is roughly 6000°. Moreover, its temperature increases rapidly as we go into the interior. My hearers realize, of course, that our sun is simply a star, one of the many thousand we see in the sky, and as such its temperature is moderate compared to some of them. While some have surface temperatures as low as 2000°, others again are favoured, if I may say so, with temperatures between 20,000 and 30,000 degrees. The coolest stars are reddish, ours is yellowish, the extremely hot ones are bluish-white. Obviously no solids can exist in such high temperatures.

The sun's light and heat energy falling upon our planet is an insignificant part of the total amount radiated by it. Let us visualize this clearly. Think of a spherical shell like a football or balloon with the sun at the centre and radius equal to the sun's distance from the earth. On this immense shell the earth would occupy but 1/2200-millionth part of the total surface. As the sun's rays are emitted equally in all directions it follows that its total output of energy is 2200-million times that received by the earth. What becomes of the remainder? Is it wasted? Possibly some of my younger hearers will be led to seek the solution of the problem.

A crude illustration or two will bring home to us the stupendous solar output of energy. If we could conceive of an ice bridge, two miles in diameter, stretching from the earth to the sun, and if by some means the whole solar radiation could be concentrated upon it, it would be melted in one second and in eight seconds more would be dissipated into vapour. Or putting it another way, the heat released yearly is equivalent to that produced by burning a mass of coal equal to 60 of our earths.

These computations can be made because we can measure with sensitive instruments the amount of heat or total radiation from the sun. Such measures indicate that the sun is not shining upon us at a constant rate. While these variations amount to only five or six per cent. yet they seem to be quite definite, and during the past ten years have been studied with the idea of their being utilized to predict weather conditions. It is only reasonable to expect a relation between such variations of its ourpourings and terrestrial temperatures.

We have known for many years that the sun passes through a cycle of changes, recurring regularly every 11½ years, such being recognized by the prevalence or absence of spots upon its surface. These sun spots are, in essence, giant eruptions like volcanoes and at the time of maximum sun spot activity the sun sends us three or four per cent. more heat than during minimum. At maximum the solar gases are in a more turbulent state and bring more heat from the interior to the surface. We would naturally expect to find a general rise in temperature on the earth with increased solar radiation, but the matter is not so simple. The change is distributed over five or six years and hence is slow in producing its effect.

But observation shows, however, that there are fluctuations of an equal amount that run their course in a week or ten days and some progress seems to have been made in correlating these with temperature changes upon the earth. The difficulties of interpretation are great, due to the fact that we are surrounded by a variable atmosphere; nevertheless, there seems some hope of success in this method of weather forecasting.

If there should prove to be longer cycles of variation of the sun's output of energy than we have yet learned of, they may

rightly be held to account, in part at least, for the ice ages known to have existed upon this earth.

The question comes to each of us: Is there any danger of the sun's supply of energy becoming exhausted? Briefly, is the sun dying? How is its heat maintained?

Enormous jets of red glowing gases can be seen shooting outwards from the sun, like flames from a fire, for thousands of miles. Does this indicate fire, as we know fire on the earth? No, the sun is not burning; combustion is not the source of its heat, otherwise it would burn itself out in a few thousands of years, with marked changes in its heat and light production as the process advanced. There is no evidence of such changes; on the other hand there is strong evidence from geological records that the sun has been emitting light and heat in prodigious quantities, not for thousands, but for millions of years.

It was suggested at one time that falls of meteoric matter into the sun would account for the sun's heat. We know that there is considerable of such matter moving through space, for many pieces of such meteoric matter come to earth, but the evidence is much against the theory, as the quantity falling into the sun would likely be quite insufficient to maintain its present output of heat.

Another explanation of the sun's output of energy is that it is due to the shrinkage of the sun's bulk under the force of gravity. If the diameter of the sun were to shrink by one mile all around, this would mean that all the millions of tons in the outer one-mile thickness would have a straight drop of one mile towards the centre. And that is not all—for the layers below this outer mile would also drop inwards, involving a tremendous movement of matter and consequent tremendous release of energy. Such a shrinkage of one mile would be sufficient to compensate for the loss of heat in fifty years. Even if this were the only source of the sun's energy we need not worry, as many millions of years would pass before the sun would be too cold to support life upon this planet.

But best of all seems the suggestion that radio-active bodies are working in the sun to maintain the sun's store of heat. This study of sub-atomic forces is in its infancy; suffice it to say that in radio-active bodies certain atoms seem to be undergoing disintegration and if such is the case in the sun then we have a source of heat for it that will last indefinitely.

IV. Facts and Fancies About the Moon

(March 28, 1928)

Two weeks ago I spoke to you on the sun and told you something of the immense amount of heat and light radiated from its surface. To-night I shall deal with the moon, a body quite insignificant in size as compared with the sun and emitting no light or heat of its own but simply basking in the sun's rays. Next to the sun, though, it is the most conspicuous of the heavenly bodies and has quite naturally been studied from earliest times.

As the moon revolves about the earth once a month we see different amounts of its illuminated surface from day to day. At the time of new moon it is between us and the sun and the bright side is turned away from us. At such times, therefore, it is invisible. After a couple of days it has moved eastward a sufficient amount so that we see the edge of the illuminated hemisphere in the form of a narrow crescent of light—the so-called new moon. As it moves still eastward we see more and more of this illuminated surface until at the time of full moon, when we are between it and the sun, we are looking directly on the illuminated half and see it complete or full. These phases were well understood by primitive peoples a thousand years ago.

Millions of years ago when our whole solar system was in the form of a vast nebulous mass, the earth and moon either formed one small portion of that mass or were separate particles in close association. Through the process of condensation over long ages of time, these bodies became solids clothed with a blanketing atmosphere. As the mass of the moon is very small, being only 1/81 of that of the earth, it was unable to hold an extensive atmosphere and to-day it enjoys no covering around its rocky and barren surface.

The moon's diameter is 2,160 miles, a little more than a quarter of that of our earth. Its distance from us is roughly 240,000 miles. These figures can be deduced by observers stationed a known distance apart on the earth,—say a few thousand miles—by noting the different position it occupies relative to the background of stars. Let us fix these relative dimensions of the sun and moon

in our mind by means of an illustration. Assume that the sun is represented by a globe two feet in diameter. On the same scale the earth could be represented by a pea, 220 feet distant, whilst the moon would be like a small pin-head only six inches from the pea (earth).

Even to the naked eye the moon is an interesting object. Bright and dark portions are seen. The dark portions are the lower lying levels of the surface, the lunar valleys, which are not illuminated by the sun's rays like the higher levels. From earliest times people have been interested in tracing imaginary objects as formed by the boundaries of these shaded valleys. Thus we have various versions of "the man in the moon", the Gibson girl and others of a like nature.

With the aid of a small telescope or opera glass these larger markings disappear and details of the surface appear. It will help in securing a correct mental picture if we think of the moon as a rocky globe, the rocks being of about similar density to those near the surface of the earth. Four main features present themselves in our telescopes,—(1) Seas, (2) Mountain ranges, (3) Craters and (4) Rills. As no water exists upon the moon the name "seas" is rather a misnomer, but as these large dark areas have a smoother surface than the rest, it may be that these were places where formerly seas existed. The mountain ranges are few in number and vary in height from one to ten thousand feet, comparable to the Malahat and Olympic Ranges near our capital city of Victoria. But while the ranges are few the surface is pitted all over with great craters, which closely resemble the volcanic craters on the earth's surface, though on an immensely larger scale. The largest terrestrial craters do not exceed 6 or 7 miles in diameter; many of those on the moon are 50 or 60 miles across, and some have a diameter of more than 100 miles. Smaller ones from 5 to 20 miles in diameter are counted by the hundred.

A typical lunar crater is nearly circular; the circumference is formed by a ring of mountains which rise anywhere from 1,000 to 20,000 feet above the surrounding country. Frequently in the centre of the crater there rises a group of peaks which attain about

the same elevation as the encircling ring. Doubtless the craters are of volcanic origin, although something must be said for the theory that meteoric masses falling into the moon when in a more plastic state may have caused some of them. They strongly remind one of the rings left by gaseous bubbles in mud, or of the blubbering of porridge when cooking.

The rills seem to be cracks in the crust of the moon. Many take the form of deep, narrow and crooked valleys. Then there are numerous straight openings, half a mile or so wide and of unknown depth, running in some cases for hundreds of miles, straight through mountain and valley, without any apparent regard for the contour of the surface. Similar lanes 5 to 10 miles wide radiate from the centre of certain craters like Tycho and may be seen as light-coloured streaks or rays near the time of full moon when the sun is shining vertically down on the surface we are looking at. Some persons have suggested that these streaks are due to a staining of the rocks by vapours ascending from rifts, too narrow to be visible. Such can be accepted only as an interesting theory, for our telescopes require the steadiest of atmospheric conditions to see rifts in the surface half a mile in width, and while there may be much narrower openings, we have no means of certifying to their actual presence.

In passing I may mention that the heights of the mountains and craters are measured by the lengths of the shadows they cast on the surface. It is found that they are much more precipitous than those of the earth's surface. It might be that if they had been subjected to the same weathering influences that have acted throughout the ages on mountain peaks on the earth that they would be less precipitous.

I have stated that there is no atmosphere on the moon. How do we know this? Amongst other ways, it is suggested by the clear cut shadows cast by the peaks. But more definitely is it evidenced by the absence of any dimming effects when the moon passes between us and any of the stars. If there were any perceptible atmosphere on the moon it would be densest at the surface, and the light from the star should be gradually reduced as the moon passes in front of it. Such is not the case; the star

preserves its brightness undiminished right up to the moment of extinction, when it is snuffed out instantaneously by the moon coming between us and the star. It may be that at one time the moon had an atmosphere of some sort but it was unable to hold it by reason of the low value of gravity at its surface. Without an atmosphere there can be no water on its surface, for such would immediately evaporate to form an atmosphere.

Without water vapour and oxygen there can, of course, be no life as we know it. And yet we would hardly be bold enough to declare that no form of vegetable life would accommodate itself to such a sun-baked surface. Indeed one astronomer who has studied the surface carefully from day to day seems to find evidences of change as if there were a growth of vegetation taking place. He stands about alone in such opinion for other explanations of the observed phenomena are more plausible.

What are the conditions as to temperature of the lunar surface? It revolves about the earth once a month keeping the same face always towards us. Thus its period of rotation on its axis is one month also. And so for half of that time it is day; for the other half, night. That is, for fourteen days the surface bakes in a temperature above the boiling point of water and for the other fourteen attains a degree of coldness not entering into the experiences of even the explorers of polar regions. The figures for the extremes are +115° and –80° Centigrade. I suppose there might be some sort of fungus growth that would adapt itself to these rapidly changing extremes of temperature, but it seems better to account for the slight changes observed as being optical rather than physical.

So much for the facts regarding the moon; let us conclude with some of the fancies that have grown up around it. Even to-day many people believe that the weather is more or less governed by the phase or change of the moon. Now the phase simply signifies a change in the amount of light received from the moon. At new moon it is zero, it increases to a maximum at full moon when it gives us only 1/600,000th part of the light of the sun; afterwards it goes through its phases in the reverse order diminishing to zero brightness at the succeeding new moon. On the average its light

throughout the month is only 1/1,000,000th part that of the sun, and how can any change in that small quantity have any appreciable effect on the weather? Moreover, the change is gradual every day, and why blame any particular day with the crime of changing the weather? It would be more rational to think of gradual changes day by day rather than by four changes per month, or worse still by an abrupt one each month at the date of new moon.

Moreover, when it is new moon in Victoria, it is new moon in Ottawa, in London, in Cape Town and in Tokio, in fact it is new moon everywhere on the earth at the same instant. Could you credit the idea that changes occur simultaneously all over the earth? If you do, you go against the facts of science, for observation continued over many years shows no correlation between weather and changes of the moon. The changes that are taking place in the output of energy of the sun, the atmospheric disturbances, the rotational effect of the earth and local modifications such as the sea and mountain ranges, all contribute to the weather experienced, and our meteorologists, studying these, are now about 85 per cent. successful in their predictions.

With this weather superstition is associated the influence of the moon on things animate and inanimate. A few years ago—there may be cases yet—some farmers killed their hogs at certain phases of the moon so that the meat would not shrivel up; they sowed their peas at definite phases—I do not recall whether at full or new moon—so that they would germinate properly. All such ideas are, of course, foolish, but they die hard.

If you have been addicted to such nonsense, forget it, for there is no scientific foundation for such superstitious beliefs.

DOH-KWI-BUHCH, (The Creator)

By Chief William Shelton*

DOH-KWI-BUHCH was the name of the great and mighty man who created the world. He started his wonderful task away over in the East and gradually worked towards the West, creating everything as he went along. He carried with him a great variety of languages and as he created each group of people, he gave them a language, being careful to select the best language he had.

While working his way West, he reached the Puget Sound country, and decided that he would go no further West or North. In his hand he still had a great number of languages left and, at a loss to know what to do with them, he scattered them all about him and to the North, and that is the very reason why there are so many different languages among the Indians of the Sound country and the North.

After Doh-Kwi-Buhch had scattered the different languages about in this wasteful fashion, the different tribes of Indians found that they could not understand one another; they were not satisfied with the way in which Doh-Kwi-Buhch had created the world—they found that the sky was much too low to suit their convenience, for the taller people would very often bump their heads on the sky. Also, people got into the habit of climbing trees and making their way into the next world, which was not as it should be.

The wiser Indians of the different tribes held a meeting and it was agreed that the people should try to shove the sky up higher, and it would be possible to do this if all the people would shove at the same time. How could they make them all understand just when they were to shove? Doh-Kwi-Buhch had given animals, birds, insects, people, all a different language and it would be difficult to make them all understand just when they were to shove.

*Chief William Shelton of the Snohomish Tribe, Tulalip Reserve, Washington, carved the 84-foot story pole erected in the city of Everett, Washington. There are twenty-eight figures on this pole, illustrating sixteen Indian legends. "Doh-Kwi-Buhch" is one of the stories. It is reprinted with the author's permission, from his book entitled "Indian Legends, or the Story of the Totem Pole"—J. A. P. (Victoria, B.C.)

Finally, one of the wiser men thought of the word "Ya-hoh", which means to lift together, and so these wise men who were attending the meeting scattered the news among the different tribes and the date for the lifting of the sky was set.

In the meantime everybody was busy making poles with which to lift the sky. You will see a bundle of these sticks or poles carved on the big story pole—they are carefully wrapped in matting and tied with Indian packing straps so that they may be preserved for a long time. You can only see the ends of the sticks protruding from the matting.

On the day set for the lifting of the sky, all the people braced their poles against the sky and the command "Ya-hoh" was given and everybody lifted as hard as they could, and they succeeded in raising the sky a little bit; after the second "Ya-hoh" the sky was raised a little higher and after the third attempt they raised the sky up to its present position.

Now it happened that just as the people had been ready to shove the sky up, three hunters who had been chasing four elk for several hours came to where Heaven and Earth nearly met and the elk jumped into the next world, and, of course, the hunters followed them, so that when the sky was raised the hunters and the elk were raised with it. To this very day, you can see them in the sky at night; the three hunters form the handle of the Dipper—the one in the centre is leading his dog, the tiny star so close to him—and the four elk form the rest of the Dipper. Then, too, you have noticed the skate-fish formation of stars in the sky [Orion]; two canoes with three Indians in each canoe and a little fish happened to be making their way into the sky when the people shoved the sky up and so they have had to remain there ever since. All the Indians know that the hunters and the little dog, the elk, the little fish, the fishermen in the canoes were on Earth once upon a time and all the tribes have the same names for these stars.

From the time the people moved the sky, there was no more jumping into the next world, and the people were contented and happy. Although they could not yet understand the languages of all the different tribes, they were happy because they had been able to use the wonderful word "Ya-hoh" and in that way they had been able to accomplish what they had set out to do.

REVIEW OF PUBLICATIONS

Geodesy. By W. M. Tobey, M.A., D.T.S., M.E.I.C., Assistant Director, Geodetic Survey of Canada.

This work constitutes Publication No. 11 of the Geodetic Survey of Canada, and is devoted to that portion of geodetic theory that may be termed the geometry of the spheroid, and its applications to geodetic computations. The author begins by placing the equation of the spheroid in a very concise form, referred to the tangent and normal at any given point on its surface as coordinate axes—a form which readily lends itself to the solution of the problems that follow.

The book is divided into five parts, comprising thirty-four propositions, each containing the investigation of some problem. The first part is devoted to the geodetic line and its relationships to the normal sections and the chord drawn between two points on the spheroid; and the second part to the effects of variations in the length and direction of a geodetic line on the latitude and longitude of its extremities. Part three contains the theory and methods of solution of spheroidal, spherical, and plane triangles; and part four the derivation of formulae for the computation of geodetic latitudes, longitudes, and azimuths of points on the terrestrial spheroid. The fifth part consists of a number of appendices, giving an index of the notation used in the text, and collections of formulae, constants, etc., useful to the computer.

Numerous references are made throughout the book, in the form of foot-notes, to the works of other writers on the subject, notably to those of the German writers, Helmert, Jordan, Zachariae, etc., to which a reader may refer for related problems. Though a free use has been made of the works of these writers the present work contains the result of much original investigation, many of the propositions being new, and all being knit together so as to form a coherent and consistent whole. It should be a valuable contribution to the literature of geodesy, and a useful aid to those engaged in geodetic computations.

L. B. S.

Handbuch der Astrophysek, edited by G. Eberhard, A. Kohlschütter and H. Ludendorff. Vol. VI, being the second part of "Das Sternsystem". 474 pages, $6\frac{1}{2} \times 9\frac{3}{4}$ inches. Berlin, Springer, 1928. Price 68.70 marks.

Though the first to be published, this is the last volume of a comprehensive treatise on Astrophysics. The present book contains: The Radial Velocities of the Stars, by K. G. Malmquist, Lund, 48 pages; Die Veränderlichen Sterne, by H. Ludendorff, Potsdam, 204 pages; Novae, by F. J. M. Stratton, Cambridge, 50 pages; and Double and Multiple Stars, by F. C. Henroteau, Ottawa, 173 pages.

It will be seen that more than half of the book is in English. The remaining volumes will appear within two years. Vols. I, II, III, dealing with the foundations of Astrophysics, are largely in German, but a considerable portion of IV and V are in English.

It is an honour to the Dominion Observatory that a member of its staff was commissioned to contribute to this great undertaking.

In each chapter there is a splendid summary of what has been accomplished in this rapidly expanding field of science, and the references to original publications are full. The work is well printed and fully illustrated, and it will be an indispensable treasury of information to the worker in astrophysics. The only regret the reviewer has to express is that the price is so high, but the limited demand and the great cost of production accounts for this. The editors and publishers are certainly to be commended for producing this valuable compendium.

C. A. C.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Professor Ritchey's Articles

Professor G. W. Ritchey is well known for the design, construction and use of the 24-inch reflector at the Yerkes Observatory and the 60-inch at Mount Wilson, and also for his part in the production of the 100-inch instrument at the latter observatory. During recent years he has been engaged in notable experiments in the construction of mirrors at the Dina Optical Laboratory at the Paris Observatory. He has consented to prepare for this Journal a series of articles describing his researches and expressing his views on the future of the reflecting telescope. They will also give a brief history of some of the developments which have taken place. The first article appears in this issue. It will be read with great interest.

Astronomy by Radio

The following subjects are being broadcast by WTAM Cleveland in a series of Astronomical Talks by Dr. Oscar Lee Dustheimer, Professor of Astronomy, Baldwin-Wallace College, Berea, Ohio: 1. The Christmas Comet of 1927; 2. The Splendor of the Heavens; 3. The New Calendar; 4. The Astronomer's Workshop; 5. The Infinitely Great and the Infinitely Small; 6. Worlds in the Making; 7. Beyond the Milky Way; 8. Celestial Giants and Dwarfs; 9. Stellar Composition.

The Number of Comets visible to the Naked Eye—(By W. F. Denning, Bristol, Eng.)

At the meeting of the Society at Toronto on February 14 last, the Rev. D. B. Marsh read an interesting paper on "Comets". The report of this paper appeared in the Journal for April 1928, p. 155. Dr. Marsh is stated to have said "that we have records altogether of about 800 or 900 comets, a small proportion only being visible to the naked eye. Of 300 seen during the last 100 years, 13 were visible without telescopic aid".

Some years ago I made an investigation of the luminosity of comets which appeared from 1850 to 1915 and found that the average number of those visible to the naked eye equalled rather more than one annually. In fact 78 comets, observable to the unaided vision, appeared within the period of 65 years mentioned above, and I gave a list of those objects in *The Observatory* for August 1915.

This referred to comets which were definitely described as perceptible without instrumental aid and I believe that the proportion stated may be relied on. Particulars were carefully referred to in the *Ast. Nach.*, *The Observatory* and other astronomical publications concerning each object.

Possibly there is a clerical error in the report of Dr. Marsh's lecture or he may have alluded to large and bright comets only, but it seems desirable to mention the above facts for there are certainly a greater number of naked eye comets than is generally supposed. Some comets are only just within the limits of our natural vision being equivalent to 5, 5½ or 6th magnitude stars, but I have included all those fulfilling the condition required, namely, those bright enough to be certainly glimpsed with the unaided eye.

C. A. C.

NEWS AND COMMENTS

Dr. H. M. Ami, president Ottawa Centre, R.A.S.C., and head of the Canadian School of Prehistory in France, will sail in the early summer to continue his investigations at Les Eyzies in the Dordogne district.

Mr. Douglas Barlow, assistant astronomer, Dominion Observatory, was recently elected English Rhodes Scholar from the Province of Quebec. He will leave for England in September to take up the study of aeronautics at Oxford University.

Professor van Biesbroek, Mrs. van Biesbroek and son Edwin motored from Yerkes Observatory, Wis., calling at the observatories in Ann Arbor and Ottawa, on their way to sail from Montreal to attend the Leiden meetings of the International Astronomical Union and to spend some months abroad.

Mr. E. A. Hodgson, seismologist, and A. H. Miller, gravitician, of the Dominion Observatory, attended the meetings of the American Geophysical Union held in Washington, April 25 and 26. Mr. Hodgson went on to the meetings of the Eastern Section of the American Seismological Society at Charlottesville, Va., April 30 to May 2. He was Acting-Chairman of the meeting and was elected Chairman of the Eastern Section.

Mr. R. Glenn Madill of the Dominion Observatory, and an assistant, will leave about the middle of June to make measurements of magnetic intensity, declination and dip at Port Burwell, Resolution Island, Cape Hopes Advance, Charles Island, Wakeham Bay, Nottingham Island and other points along Hudson Strait. The data, to be secured primarily for the purpose of extending the study of secular variation, will have an immediate practical application in navigation. Aurorae and magnetic disturbances will be studied as well. The party will be accomodated on SS. Montcalm through the courtesy of the Department of Marine and Fisheries.

Director J. S. Plaskett of the Dominion Astrophysical Observa-

tory, Victoria, who has been ill for some time, is taking a few months' rest to be followed by an ocean voyage. Mr. W. E. Harper, Assistant Director, is in charge in his absence.

WONDER, PROMISE, DOUBT, CONFUSION, HUMILITY

Twinkle, twinkle little star,
How I wonder what you are,
Up above the world so high,
Like a diamond in the sky.—(ANN AND JANE TAYLOR).

Twinkle, twinkle little star,
I shall find out what you are,
When unto the midnight sky,
I my spectroscope apply.—(SIR ROBERT BALL).

Twinkle, twinkle little star,
Have I found out what you are
Though with instruments so fine
I have read you line by line?—(J. L. O'C.).

Twinkle, twinkle little star,
Now I question, though you are
To-night a diamond shining blue,
To-morrow what will be your hue?—(R. E. DEL.).

Twinkle, twinkle little star,
Still I know not what you are,
Like a veil, you throw o'er me,
A profound humility.—(E. A. H.).

A 19-inch reflecting telescope has been constructed by Dr. R. K. Young at the University of Toronto. The mirror is of pyrex glass, which has a much smaller coefficient of expansion than the glass ordinarily used for this purpose. The focal length is about 120 inches. The tube is of the open framework type, and the driving clock is actuated by an electric motor, which is controlled by a standard sidereal clock, on the principle applied by Gerrish at the Harvard Observatory. It is hoped to use the telescope in a students' observatory when a suitable location for the latter can be found.

Professor and Mrs. C. A. Chant expect to sail on June 22 to attend the International Astronomical Union at Leiden and to spend some time on the Continent and in England.

R. E. DEL.

MEETINGS OF THE SOCIETY

AT MONTREAL

The Treasurer's Financial Statement for Montreal Centre for the year beginning November 1, 1926, ending November 1, 1927, was not ready at the time of the Annual General Meeting of the Society. It is as follows:

RECEIPTS

Balance carried forward from last year	$29.30
5 Fees collected for 1926	10.00
94 Fees collected for 1927	188.00
Grant received from a local member	100.00
Bank interest	0.49
	$327.79

DISBURSEMENTS

Remitted Fees to General Treasurer	198.00
Expenses—Lecture, Dr. DeLury	10.00
Dr. Shaw	3.50
Telegrams	3.00
Flowers, Taxi and Exchange on cheque	3.15
Janitor service at meetings	7.50
Lantern Operator's services at meetings	8.00
Printing, Stationery and Postage	23.50
Cash in Bank and on Hand	71.14
	$327.79

AT VICTORIA

January 24, 1928.—Meeting opened with President J. A. Pearce in the chair. The following new members were elected:

Mrs. M. A. Muskett, Collegiate Schools, Rockland Ave., Victoria, B.C.

Mr. A. H. Spurr, 3251 Linwood Ave., Victoria, B.C.

Mr. W. E. Harper gave a short talk on the gaseous envelope surrounding the star Nova Aquila.

The main address of the evening was given by Dr. Daniel Buchanan of the University of British Columbia, Honorary President of the Victoria Centre, Royal Astronomical Society of Canada. Dr. Buchanan's subject was "Astronomical Discoveries". He dealt with various astronomical discoveries beginning

with the speculations of Aristotle on the motions of the earth and sun. The address had to do mainly with the solar system and Dr. Buchanan gave an interesting account of the discovery of some of the other planets and the planetoids. A number of problems of celestial mechanics were touched upon and the lecture was illustrated by a number of beautiful slides of astronomical objects.

February 21.—The meeting was held at Victoria College and was opened by the President, J. A. Pearce. Mr. Pearce announced the election of Mr. W. E. Harper to the presidency of the federal society and suggested that Mr. Harper take the chair for the evening but Mr. Harper declined. The members present showed their pleasure at Mr. Harper's election by hearty applause. The secretary gave a short talk on the Zodiacal Light and Mr. W. H. Christie made an announcement of astronomical events for the month.

The address of the evening was delivered by Dr. J. S. Plaskett who chose as his subject "The Motions of the Stars". Dr. Plaskett first discussed the methods of detecting stellar motions. The motion of a star in the line of sight could be determined by means of the spectroscope while the motion across the line of sight could be determined by finding the change of position of the star from year to year.

The latter part of the address was devoted to a discussion of the systematic motions of the stars and their interpretation in terms of the motion of the stellar universe as a whole. The most attractive hypothesis and the one which appeared most closely to fit the facts of observation would attribute the observed velocities of many of the stars to a rotation of the galaxy about a distant centre. Different parts of the galaxy rotated with different angular velocities and the axis of rotation was perpendicular to the plane of the Milky Way.

Dr. Plaskett showed how the observations of stellar velocities made by himself and other observers could be used to determine the existence of such motions in the galaxy and also to determine the direction of the axis of rotation. Results of investigations at Victoria were in excellent agreement with results of similar investigations made by Oort in Holland and decidedly tended to confirm the hypothesis of a rotation of the galaxy. The lecture was illustrated by a number of diagrams and photographs of spectra. (The address in full appears in the April JOURNAL.)

March 23.—The Society met at Victoria College at 8 p.m. with President J. A. Pearce in the chair. The following new members were elected:

Miss Phyllis Deaville, 3070 Washington Ave., Victoria, B.C.
Mrs. Stuart Mannell, 1176 Yates St., Victoria, B.C.
Mr. Charles Hartley, 430 St. Patrick St., Victoria, B.C.
Mrs. Charles Hartley, 430 St. Patrick St., Victoria, B.C.

The president then called on Mr. W. E. Harper for a short address on The Age of the Earth. Mr. Harper briefly outlined the various methods of estimating the earth's age. The method which was considered most reliable depended on the estimation of the amount of lead, resulting from the radio-active disintegra-

tion of heavier metals, which could be found in the oldest strata of rocks. The age of the earth as estimated by this method is of the order of 4,000,000,000 years.

The paper for the evening on "The History of the Earth from Pre-Cambrian to the Present Time" was then given by Dr. Merton Y. Williams, F.R.S.C., formerly geologist of the Canadian Geological Survey and now professor of Stratigraphy and Paleontology at the University of British Columbia.

Dr. Williams in a most interesting and instructive address traced the geological and biological changes which have taken place on the earth since the earliest appearance of fossils in the later Pre-Camb.ian era. Particularly interesting were his remarks on the mesozoic and cenozoic, the age of giant reptiles, the glacial ages and the post-glacial mammoths of the North American Continent. The lecture was richly illustrated with lantern slides.

During the discussion following the lecture Mr. J. Duff, Past President, recited a poem on evolution, entitled "Similar Cases". Rev. Robert Connell, Vancouver Island's authority on Natural History moved the vote of thanks which was seconded by Mr. W. S. Drewry.

April 17.—The meeting was held in the Girls' Central School, Victoria, and was opened by the president.

Mr. N. C. Stewart, 1137 North Park St. was elected a member of the Society.

Mr. C. S. Beals then gave a short talk on the design and construction of very large telescopes, having particular reference to the suggestion of Pease of Mount Wilson who has drawn up a design for an instrument having a mirror 25 feet in diameter.

The principal part of the evening's programme consisted of a lecture by Dr. H. Zanstra of the University of Washington. Dr. Zanstra chose as his subject "The Nebulae, the Luminous Clouds of Space", and his address, which was illustrated by many beautiful lantern slides, consisted in part of a comprehensive survey of present day knowledge of the nebulae, and in part of a discussion of the results of some of his own recent investigations into the nature of the nebulae and the temperatures of the stars which caused their luminosity. Dr. Zanstra's researches indicated temperatures as high as 134,000° for the stars forming the nuclei of planetary nebulae.

A vote of thanks to the speaker was moved by Mr. P. H. Elliott, seconded by Mr. P. S. Langton.

C. S. Beals,
Secretary-Treasurer.

Victoria Centre Extension Lectures

It has always been the custom of all the Centres of the Society to supplement their regular lecture programmes by giving additional lectures from time to time at outside points within their jurisdiction. Such lectures always prove popular and frequently bear fruit in getting new members for the Society.

Far be it from the Victoria Centre to claim that it is discharging the responsibilities of the Constitution, Article 3, Sec. "a" in a model manner, but the

Centre has during the past years carried out an extensive programme in this regard. The other Centres may be interested, therefore, in reading about our activities during the past few months which are not included in the annual report printed in the March issue of the JOURNAL.

1. 1927, Nov. 16, F. N. Denison — Farmers Institute at Sooke, B.C., "The Climate of British Columbia".
2. " 17, F. N. Denison—Victoria's Teachers' Association, "The Climate of British Columbia".
3. " 20, Rev. W. Lashley Hall—United Church, White Rock, B.C., "The Heavens Declare the Glory of God".
4. " 24, Rev. W. Lashely Hall—White Rock, B.C., "The Solar System".
5. Dec. 6, J. S. Plaskett—"Strathcona Lodge" Shawnigan Lake, B.C., "Journey Through Space".
6. " 13, A. Waring Giles—Vernon, B.C., "The Constellations".
7. 1928, Jan. 9, F. N. Denison—Victoria Gyro Club, "The Dominion Meteorological Service in British Columbia".
8. " 10, F. N. Denison—St. Columbia's Brotherhood, Victoria, B.C., "The Climate of British Columbia".
9. " 16, J. A. Pearce—Aloha Club, Tacoma, Wash., "Facts and Fancies of the Stars".
10. " 20, F. N. Denison—Royal Yacht Club, Victoria, B.C., "The Winds and Weather of the North Pacific Coast".
11. Feb. 7, F. N. Denison—Metropolitan Brotherhood, Victoria, B.C., "The Climate of British Columbia".
12. " 17, W. E. Harper—Royal Yacht Club, Victoria, B.C., "Cruising Among the Stars".
13. " 29, F. N. Denison—St. Mary's Young Peoples Association, "Earthquakes and how they are Recorded".
14. March 3, J. A. Pearce—Masonic Temple, Victoria, B.C., "What We Know about Mars".

During the two weeks, December 5-16, 1927, the ten reels of astronomical motion pictures procured by Prof. P H. Elliott, President, 1926-27, from the Department of Education, Ontario, were shown by Prof. Elliott to the greater number of public schools in the city.

The latest step in popularizing astronomy has been the series of bi-weekly radio talks by W. E. Harper, President of the Federal Society, broadcasted from Station CFCT, Victoria, B.C. Mr. Harper to date has given six of these talks which will be published in the coming issues of the JOURNAL.

J. A. PEARCE,
President, Victoria Centre.

Victoria, B.C.,
April 4, 1928.

AT WINNIPEG

February 3, 1928.—The meeting was held in Lecture Theatre "A" University Science Building.

The speaker of the evening was Professor Frank Allen, F.R.S.C., who lectured on "Relativity". The popular and indeed the universal scientific interest in Relativity, the lecturer pointed out, began in 1919 when during a total eclipse of the sun photographs of the stars in its vicinity showed that they were apparently displaced away from the sun. As the stars could not be displaced themselves, the effect must be due to the bending of rays of starlight by the huge gravitational attraction of the sun. This effect was predicted by Einstein in his theory of Relativity, and the experimental verification established the theory.

The earliest Greek conception of the solar system was a heliocentric theory that is, the sun was the centre. Gradually this was replaced by a geocentric theory—with the earth as a centre—due largely to Ptolemy. The Ptolemaic system lasted 15 centuries and was then replaced by the heliocentric theory of Copernicus. This was given a firm basis by the gravitational theory of Newton.

It has since then been assumed that nothing more could be said about the structure of the universe. But Einstein has formulated a new conception called "Relativity", which is highly mathematical in character. The new conception leads to revolutionary views of the universe. When matter is in motion its mass increases until at the velocity of light (186,000 miles per second) mass becomes infinitely great. A stick when moved in the direction of its length becomes shorter with increasing velocity until at the velocity of light it shrinks to nothing. Time also becomes longer the faster we move, until at the velocity of light a second of time becomes an eternity.

Relativity leads to a new law of gravitation, more accurate than Newton's, which has led to the prediction of three things never before explained. The chief of these is the bending of the rays of light by gravitation.

The theory of Relativity involves a new view of the universe, of space and time and matter, and their relationship to each other. These relationships involve many results which are paradoxical to us because they lie outside the range of our ordinary mental experience and habits of thought.

The lecture was illustrated by diagrams and suitable apparatus.

S. C. Norris, *Secretary.*

AT TORONTO

March 13.—The meeting was held in the Physics Building of the University. Mr. A. F. Miller occupied the chair.

Mr. Miller called on Prof. L. B. Stewart as the speaker for the evening on the subject announced "A trip to the Yukon in the early days". Thirty years ago the eyes of half the world were turned on this corner of our Dominion as stories of the fabulous wealth of gold being unearthed there reached civilization. The fever of gold did not affect Prof. Stewart, but he made the arduous trip to

increase his professional experience as a surveyor, and to add to his knowledge of the wilderness regions of Canada. There were at that time three general routes of travel. First the overland route via Edmonton, second the long sea voyage to St. Michael's and thence up the Yukon river to Dawson, third by way of Skagway at the head of the Lynn canal over the White Pass to Lake Bennett and then down the river to Dawson. The latter route was the one followed by Prof. Stewart. The recital of the exciting events of those early days in the gold rush was told in an exceedingly interesting way, the lecturer's viewpoint being different from the average explorer. It was quite apparent from what the lecturer said that even the goldseeker was dependent in some measure on the astronomer for the accurate determination of his location.

March 27.—The meeting was held in the Physics Building of the University at 8 p.m. Mr. J. R. Collins in the chair.

Mr. A. F. Miller spoke briefly on sunspot periods—Maximum period is now approaching.

Mt. W. Gore told of his observation of the phenomenon of divergent rays of light from the sun due to peculiar cloud formation.

Mr. Collins followed calling attention to the recent literature on Millikan's Rays. He spoke of the possibility of matter being formed in space and shot forward at great velocity. The earth in this way may be receiving matter continually. Mr. Collins pointed out that this was merely a speculation, and could hardly yet be accepted as fact.

The chairman then called on Professor A. T. DeLury for the paper for the evening on "Civilization's Debt to Mathematics".

Civilization, a process or a progress as well as a result, embraces all those advances that make for comfort and satisfactory living, and all those advances which may be spoken of as artistic and intellectual. While mathematics contributed much to the former, the speaker chose to speak rather of what mathematics had done in readjusting the human mind. Mathematics, as touching on civilization, began with the Greeks. Geometry arising, it is said, out of the needs of the surveyor, was by them made and regarded as a science, and was studied for its beauty and artistic satisfaction. As organised by Euclid it became the model for scientific presentation. Next the astronomy of Copernicus reacted markedly on the human mind, giving the earth and man a new relative place, with all that is implied on this. The work of Kepler and Galileo prepared the way for Newton who probed into causes, finding the key of explanation and giving a new impetus to enquiry. Later the speculative geometers, Gauss, Lobatchevsky, Bolza and Riemann developed a new attitude towards space, and Minkowski, joining time and space in close association cleared the way for the work of Einstein which presents a readjusted universe.

April 10.—The Meeting was held in the Physics Building at 8 p.m., Dr. R. K. Young in the chair.

The following were elected to Membership in the Society:

Mrs. R. H. Cobb, 78 Grosvenor St., Toronto.

Miss Gladys Reynolds, 78 Grosvenor St., Toronto.
Prof. Dr. Y. Väisälä, Turku, Finland.
Mr. John W. Streeter, 474 Yale Station, New Haven, Conn., U.S.A.
Mr. Jacques Morency, 193 rue Royale, Trois-Rivieres, P.Q.

The chairman stated that the announced lecturer, Prof. G. R. Anderson, had been unexpectedly called to New York, and that Dr. C. A. Taylor, President of the Optometrical Association, who was to lecture before the Illuminating Engineering Society this evening would give his lecture to the combined audiences of the I.E.S. and the R.A.S.C.

While waiting for their arrival Mr. F. T. Stanford showed some very interesting moving pictures on the screen.

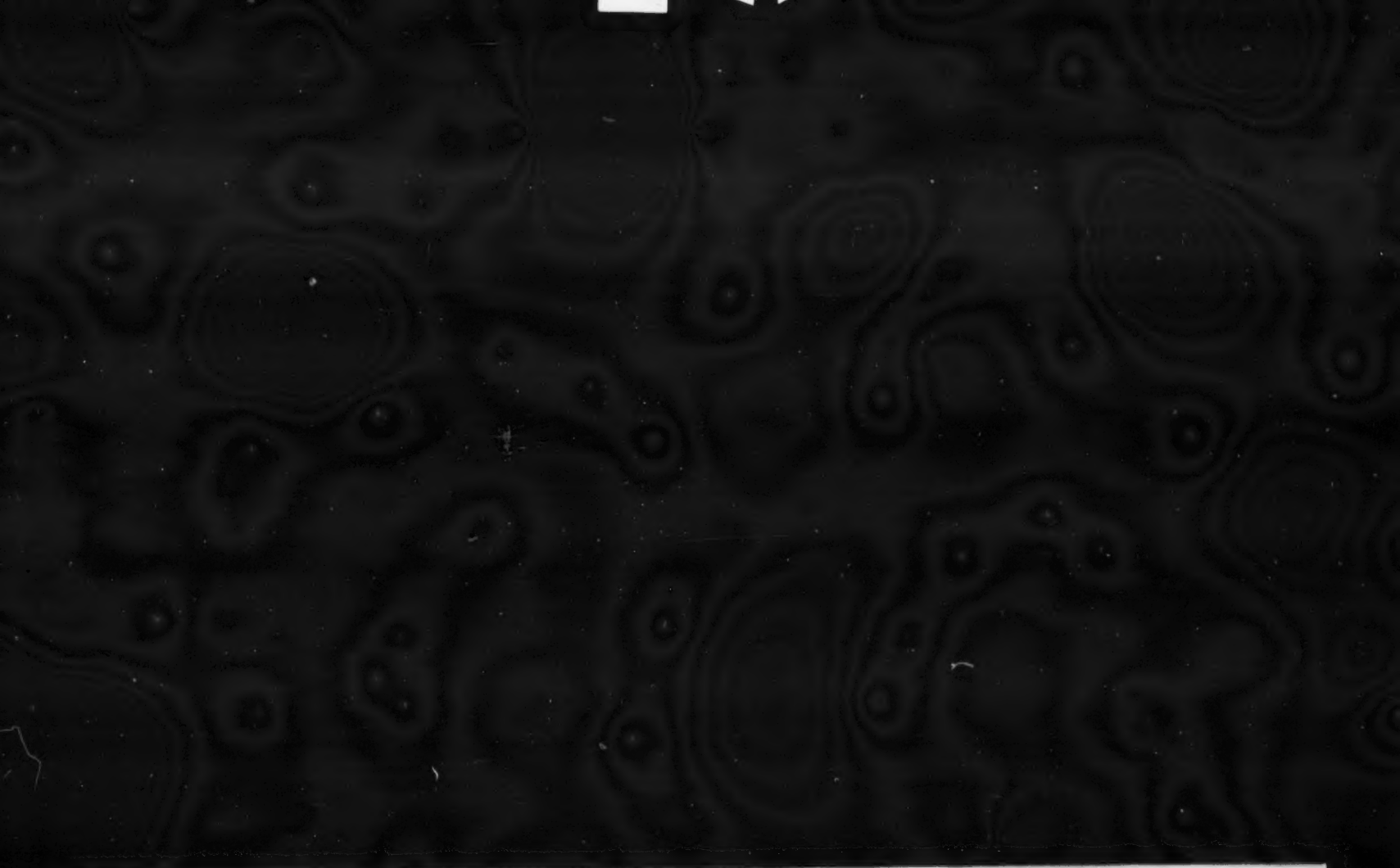
Dr. Young then asked the President of the Illuminating Engineering Society to take the chair, who then introduced the lecturer.

Dr. C. A. Taylor then spoke on the "Conservation of Sight". He gave some interesting details of the condition of eyesight in Canada, one-quarter of the population wearing glasses, while 14,000 have suffered the loss of one eye, and 1,000 in the Province of Quebec are blind. The lecturer also spoke of the work of the Ophthalmic Division of the Dominion Government.

April 24.—The meeting was held in the Physics Building of the University at 8 p.m., Mr. J. R. Collins in the chair.

The paper for the evening was by Dr. J. B. Fraser, "The relation of Astronomy to Medicine in early and later times". One of the earliest physicians mentioned was Aesculapius who, according to Homer, was skilled in the arts of Astrology and Medicine. Hippocrates, born about 460 B.C. was said to be a descendant of his and we find in him the same belief in the influence of climate and season on health and disease, and in the movements of the moon and stars controlling the conformation of the body and disposition of the mind. Galen, born about 130 A.D. is to-day often called the "Father of Medicine". He studied the science of astrology and connected the changes of the moon with the crises of diseases. Paracelsus, born in 1493, declared that the science of medicine was divided into four departments, viz., Philosophy, Astronomy, Alchemy, and Physical Science. A knowledge of nature is the foundation of the science. For ages it has been thought that the Zodiacal signs affected the life of the body according to the sign the person was born under. The present bond between astronomy and medicine is a very loose one, yet the speaker believes that a union of forces would help prevent disease, and thus benefit the public. For instance—when the astronomer has reason to believe that an unusual wave of heat, cold or rain is approaching he can warn the public of that danger to health, at the same time the physician can suggest means to prevent the ill effects of such conditions. Consequently the public would be advised how to prevent rather than cure disease. One would have to enlist the help of the daily newspapers, and that would likely be given in the interest of public health. In conclusion a weather and health bulletin was submitted.

E. J. A. Kennedy, *Recorder.*



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